

Claims

- [c1] 1. A method of controlling a hybrid electric vehicle having a power unit, an energy storage device, and a controller including a state machine having a plurality of states comprising a sequence of the following steps:
- (a) determining the value of a parameter of said storage device;
 - (b) if said machine is in an OFF state, which requests that said power unit be off, and said parameter is less than an ON level, causing said machine to transition from said OFF state to an OPPORTUNISTIC state which request that said engine be kept on if already on;
 - (c) if said machine is in an ON state, which requests that said power unit be on, and said parameter is greater than said ON level causing said machine to transition from said ON state to said OPPORTUNISTIC state;
 - (d) if said machine is in said OPPORTUNISTIC state and said parameter is less than a MIN level, said MIN level being less than said ON level, causing said machine to transition from said OPPORTUNISTIC state to said ON state; and
 - (e) if said machine is in said OPPORTUNISTIC state and said parameter is greater than an OFF level, said OFF

level being greater than said ON level, causing said machine to transition from said OPPORTUNISTIC state to said OFF state.

- [c2] 2. The method of Claim 1 wherein said storage device is a battery.
- [c3] 3. The method of Claim 2 wherein said power unit is an internal combustion engine.
- [c4] 4. The method of Claim 3 wherein said parameter is the state of charge (SOC) of said battery.
- [c5] 5. The method of Claim 3 wherein said parameter is the discharge power limit (DPL) of said battery calculated on a real time basis.
- [c6] 6. The method of Claim 3 wherein said levels are dependent on the position of a vehicle transmission.
- [c7] 7. A method of controlling a hybrid electric vehicle having a power unit, an energy storage device, a transmission, and a controller including a state machine having a plurality of states including an ON state which requests that said power unit be on, an OFF state which requests that said power unit be off, and an OPPORTUNISTIC state which request that said engine be kept on if already on, comprising a sequence of the following steps:

- (a) determining the value of a parameter of said storage device;
- (b) if said machine is in said ON state and said parameter is greater than an ON level causing said machine to transition from said ON state to said OPPORTUNISTIC state;
- (c) if said machine is in said OFF state and said parameter is less than an ON level causing said machine to transition from said OFF state to said OPPORTUNISTIC state;
- (d) if said machine is in said OPPORTUNISTIC state and said parameter is less than a MIN level, wherein said MIN level is less than said ON level, causing said machine to transition from said OPPORTUNISTIC state to said ON state;
- (e) if said machine is in said OPPORTUNISTIC state and said parameter is greater than an OFF level, wherein said OFF level is greater than said ON level, causing said machine to transition from said OPPORTUNISTIC state to said OFF state.

[c8] 8. A controller for a hybrid electric vehicle having a power unit, and an energy storage device, said controller comprising:
a state machine having a plurality of states including an ON state which requests that said power unit be on, an OFF state which requests that said power unit be off, and an OPPORTUNISTIC state which request that said engine

be kept on if already on;
means for determining the value of a parameter of said storage device;
means for requesting a transition of said machine from said OFF state to said OPPORTUNISTIC state if said parameter drops below an ON level;
means for requesting a transition of said machine from said ON state to said OPPORTUNISTIC state if said parameter rises above said ON level;
means for requesting a transition of said machine from said OPPORTUNISTIC state to said ON state if said parameter drops below a MIN level which is less than said ON level;
means for requesting a transition of said machine from said OPPORTUNISTIC state to said OFF state if said parameter rises above an OFF level which is greater than said ON level.

[c9] 9. The controller of Claim 8 wherein said vehicle includes a transmission and the MIN level, ON level, and OFF level are one set of values when the transmission is in a drive position and another and respectively higher set of values when the transmission is in a reverse position.

[c10] 10. A method of controlling the starting and stopping of the power unit of a hybrid electric vehicle having an energy storage device, and a controller including an arbi-

trator for commanding the power unit to start or stop based on an evaluation of arbitrator requests comprising a sequence of the following steps:

(a) determining the value of a parameter of said storage device;

(b) if the engine is off and the level of said parameter is greater than an ON level, issuing an arbitrator request to turn the engine off;

(c) if the engine is off and the level of said parameter drops below said ON level, issuing an arbitrator request that the engine be kept on if the engine is presently on;

(d) if the level of said parameter is less than a MIN level issuing an arbitrator request that the engine be turned on until the level of said parameter achieves said ON level and thereafter issuing a request that the engine be kept on if the engine is presently on.

[c11] 11. The method defined in Claim 9 wherein said ON level has a value that is between said MIN level and said OFF level.

[c12] 12. The method of Claim 10 wherein said vehicle includes a transmission and said controller stores first and second sets of MIN, ON, and OFF levels, the first set for use when the transmission is in a drive position and the second set for use when the transmission is in a reverse position.

- [c13] 13. The method of Claim 12 wherein the values of said second set are higher than the respective values of said first set.
- [c14] 14. A method of controlling a vehicle having a primary power source and an energy storage device, the method comprising:
determining one or more operating parameters of the energy storage device;
transitioning to a new operating state of a state machine based at least on the operating parameter of the energy storage device and the present state of the state machine;
requesting that the operation of the primary power source be changed to ON or OFF or maintained on depending on the state of the state machine.
- [c15] 15. A method of controlling a vehicle having a primary power source and an energy storage device, the method comprising:
determining an operating parameter of the energy storage device;
providing the value of said parameter as an input to a state machine having an ON state wherein the state machine outputs a primary power source ON request, an OFF state wherein said state machine outputs a primary

power source OFF request, and an OPPORTUNISTIC state wherein said state machine outputs a request that the primary power source be maintained ON if already ON and outputs a DON'T CARE request if the primary power source is OFF;

transitioning said state machine from said OPPORTUNISTIC state to said ON state or said OFF state on the basis of the value of said operating parameter.